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14. ABSTRACT There has been a lack of investigations related to low yield explosives instigated by terrorist on small but high occupancy buildings. Also, mitigating the threat of terrorist attacks against high occupancy buildings with network equipment essential to the mission of an organization is a challenging task. At the same time, it is difficult to predict how, why, and when terrorists may attack these assets. Many factors must be considered in creating a safe building environment. Although it is possible that the dominant threat mode may change in the future, bombings have historically been a favorite tactic of terrorists. Ingredients for homemade bombs are easily obtained on the open market, as are the techniques for making bombs. Bombings are easy and quick to execute. This paper discusses the problems with and provides insights of experience gained in analyzing small scale explosions on older military base buildings. In this study, we examine the placement of various bombs on buildings using the shock wave simulation code CTH and examine the damage effects on the interior of the building, particularly the damage that is incurred on a computer center. These simulation experiments provide data on the effectiveness of a building's security and an understanding of the phenomenology of shocks as they propagate through rooms and corridors. Its purpose is to motivate researchers to take the seriousness of small yield explosives on moderately sized buildings. Visualizations from this analysis are used to understand the complex flow of the air blasts around corridors and hallways. Finally, we make suggestions for improving the mitigation of such terrorist attacks. The intent of this study is not to provide breakthrough technology, but to provide a tool and a means for analyzing the material hardness of a building and to eventually provide the incentive for more security. The information mentioned in this paper is public domain information and easily available via the internet as well as in any public library or bookstore. Therefore, the information discussed in this paper is unclassified and in no way reveals any new methodology or new technology.					
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Damage Assessment of Mission Essential Buildings based on Simulation Studies of Low Yield Explosives

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Abstract

There has been a lack of investigations related to low yield explosives instigated by terrorist on small but high occupancy buildings. Also, mitigating the threat of terrorist attacks against high occupancy buildings with network equipment essential to the mission of an organization is a challenging task. At the same time, it is difficult to predict how, why, and when terrorists may attack these assets. Many factors must be considered in creating a safe building environment. Although it is possible that the dominant threat mode may change in the future, bombings have historically been a favorite tactic of terrorists. Ingredients for homemade bombs are easily obtained on the open market, as are the techniques for making bombs. Bombings are easy and quick to execute. This paper discusses the problems with and provides insights of experience gained in analyzing small scale explosions on older military base buildings. In this study, we examine the placement of various bombs on buildings using the shock wave simulation code CTH and examine the damage effects on the interior of the building, particularly the damage that is incurred on a computer center. These simulation experiments provide data on the effectiveness of a building's security and an understanding of the phenomenology of shocks as they propagate through rooms and corridors. Its purpose is to motivate researchers to take the seriousness of small yield explosives on moderately sized buildings. Visualizations from this analysis are used to understand the complex flow of the air blasts around corridors and hallways. Finally, we make suggestions for improving the mitigation of such terrorist attacks. The intent of this study is not to provide breakthrough technology, but to provide a tool and a means for analyzing the material hardness of a building and to eventually provide the incentive for more security. The information mentioned in this paper is public domain information and easily available via the internet as well as in any public library or bookstore. Therefore, the information discussed in this paper is unclassified and in no way reveals any new methodology or new technology.

Keywords: CTH, terrorists, buildings, simulation, phenomenology of shock waves, blast, shock waves, TNT, explosives

1. Introduction

It is clear that terrorism will continue to plague societies in the 21st Century. Although it is difficult to accurately gauge the future direction of the terrorist threat confronting the United States, current trends and indicators provide some clues as to the types of challenges that can be anticipated, such as fewer but more destructive attacks such as 9/11[1]. This does not mean that all – or even most – acts of terrorism will involve large scale explosives or yield high casualty figures. Small scale acts of terrorism, such as pipe bombs and letter bombs, will, in all likelihood, continue to occur. Even though the frequency of such attacks in the United States has fallen dramatically during the past decade when compared to levels recorded in the 1970's and 1980's [1], small scale bombs in the 21st Century are becoming more sophisticated and more powerful which is why this paper emphasizes back-pack size weapons.

Security design intended to limit or mitigate damage from a bomb placed in a backpack assumes that the bomb is detonated at so-called critical locations. Design of such bombs unfortunately is public domain information and is readily available in the internet [2]. In this study, we look at several critical locations, a bomb placed at the door and one placed just outside several strategic locations as depicted with a red dot in figure 1. The larger room in this case represents a server room or computer room containing critical data for an organization. This situation is typical for many unclassified as well as classified buildings. The critical location of an explosion is a function of the site, the building layout, and the security measures in place. Small weapons can cause the greatest damage when brought into vulnerable, unsecured areas of a building's interior, such as a building lobby room. As will be shown in this article, small weapons can also cause a great deal of damage when placed at the exterior of a building. In general, the largest credible explosive size is a function of the security measures in place. Each line of security may be thought of as a sieve, reducing the size of the weapon that may gain access. Therefore the largest weapons are considered in totally unsecured public space (e.g. in a recyclable bin in a lobby), and the smallest weapons are considered in the most secured areas of a building (e.g., a briefcase placed in an inconspicuous place).

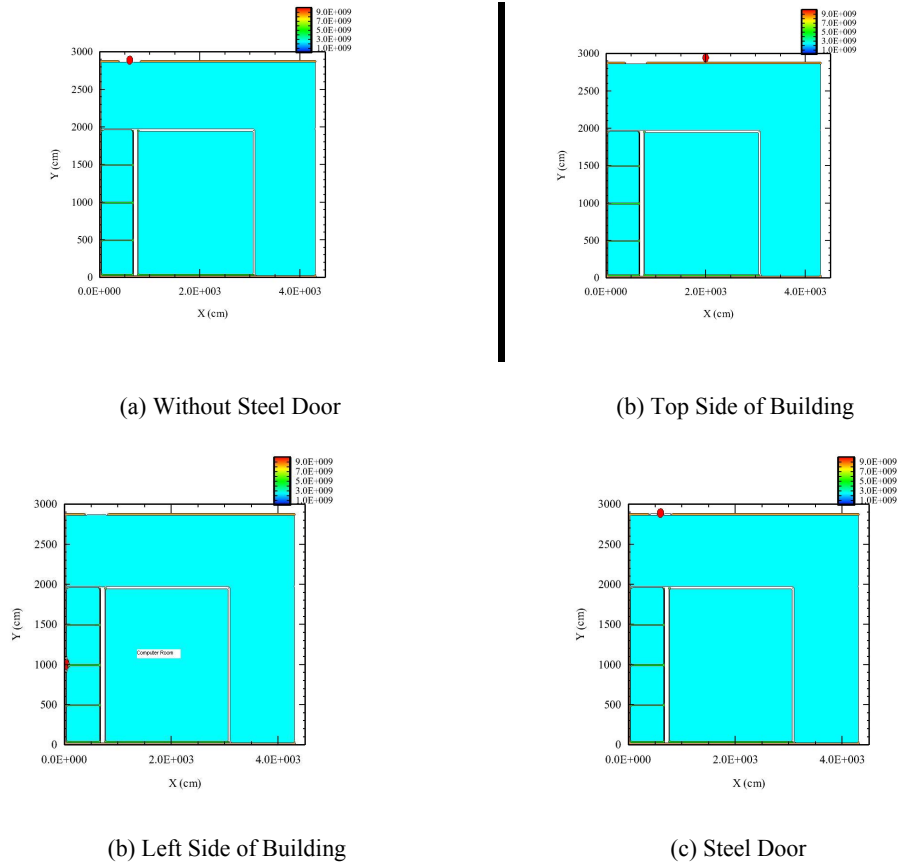


Figure 1: Problem Setup (red dot is placement of explosive)

Two parameters define the design threat: the weapon size, measure in equivalent pounds of TNT, and the standoff. The standoff is the distance measured from the center of gravity of the charge to the component of interest [2].

The design weapon size is usually selected by the owner in collaboration with security and protective design consultants (i.e., engineers who specialize in the design of structures to mitigate the effects of explosions). Although there are few unclassified sources giving the sizes of weapons that have been used in previous attacks throughout the world, security consultants have valuable information that may be used to evaluate the range of charge weights that might be reasonably considered for the intended occupancy. Security consultants draw upon the experience of other countries such as Great Britain and Israel where terrorist attacks have been more prevalent, as well as data gathered by U.S. sources. The following is a summary of their findings [1]:

1. The likely target is often not the building under design, but a high risk building that is nearby. Historically, more building damage has been due to collateral effects than direct attack.
2. It is difficult to quantify the risk of man-made hazards. However, qualitatively it may be stated that the chance of a large-scale terrorist attack occurring is extremely low. A smaller explosive attack is far more likely.
3. Providing a level of protection that is consistent with standards adopted for federal office buildings enhances opportunities for leasing to government agencies in addition to providing a clear statement of regarding the building's safety to other potential tenants.
4. The added robustness inherent in designing for a bomb placed in a back-pack of moderate size will improve the performance of the building under all explosion scenarios.

2. Problem Setup

The analysis performed in this paper used CTH [3], a computational structural mechanics software program out of Sandia National Laboratories at Albuquerque, New Mexico. CTH is a multi-dimensional, multi-material, finite-volume shock physics code that models shocks and the multiphase behavior of materials. The buildings under study are small buildings (ranch styles of approximately 100 ft. by 130 ft), but non-the-less, very common in many military installations. This type of building is constructed of a wood frame with cement (masonry) blocks approximately 10 inches thick on its exterior.

The following models were utilized in the modeling of the materials used in the simulation: Mie Gruniesen, Shock Hugoniot, Jones-Wilkins-Lee (JWL) EOS for explosive detonation products, Fracture model based on strength of material using the Hohnson-Cook Scalar Damage Model, Viscoplasticity (using Yield Stress Dependence), Hydrodynamic Boundary Conditions (for simulating an infinite or semi-infinite media). Figure 2 depicts the pressures in dynes/cm² that is accumulated in the buildings from the explosive power of TNT. Pressures climb to above the critical level of 30 psi in some of the areas of the building.

3. Discussion and Results

The shock wave from an external explosion causes an almost instantaneous increase in pressure on nearby objects to a maximum value. This is followed by a brief positive phase during which the pressure decays back to its ambient value, and a somewhat longer but much less intense negative phase during which the pressure reverses directions.

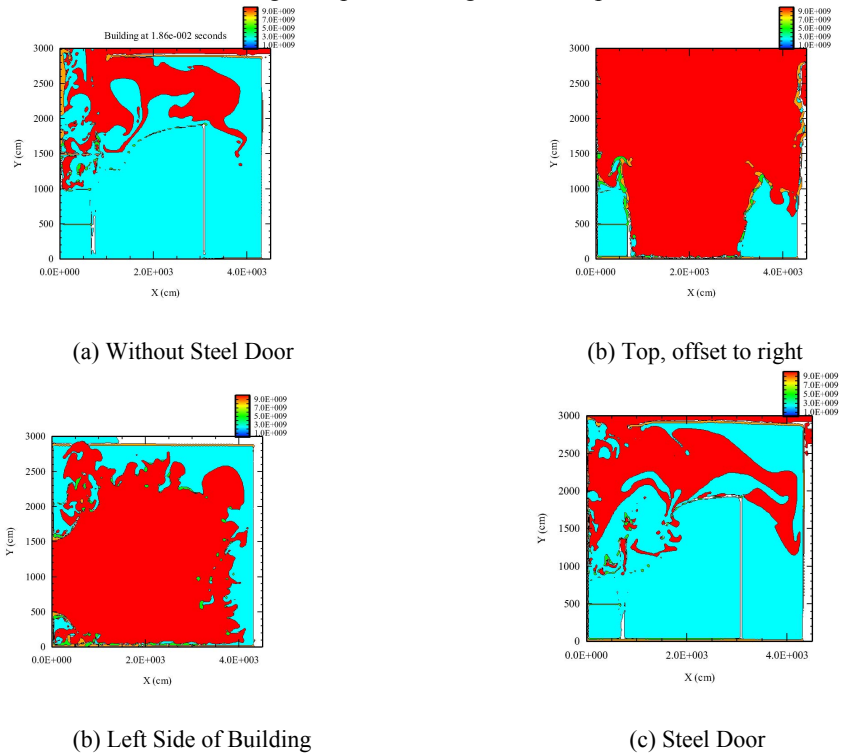


Figure 2: Extent of Debris

Figure 2 also depicts the extent of the debris that is distributed as a function of the placement of an explosive based on figure 1. The largest amount of damage is incurred when an explosive is placed on the side of a building other than the doorway. A steel door apparently does not mitigate the situation.

Figure 3 depicts the pressure distribution incurred with different placement of explosives on the outside of a building. The pressure range that occurs in such explosions is from 145 PSI to 1400 PSI as shown in Figure 3. As shown in the figures, these type of explosions may be lethal for any person subjected to an explosion placed in any part of the outside of the building, except at the doorway, which would be the least lethal. While a human body can withstand up to 30 psi of simple overpressure, most blast deaths result from the collapse of occupied buildings from people being blown into objects, or from buildings or smaller objects being blown onto or into people. Clearly then, it is impossible to calculate with any precision how many people would be killed by a given blast – the effects would vary from building to building. In addition, under the pressure listed in figure 3, computer equipment would be devastated.

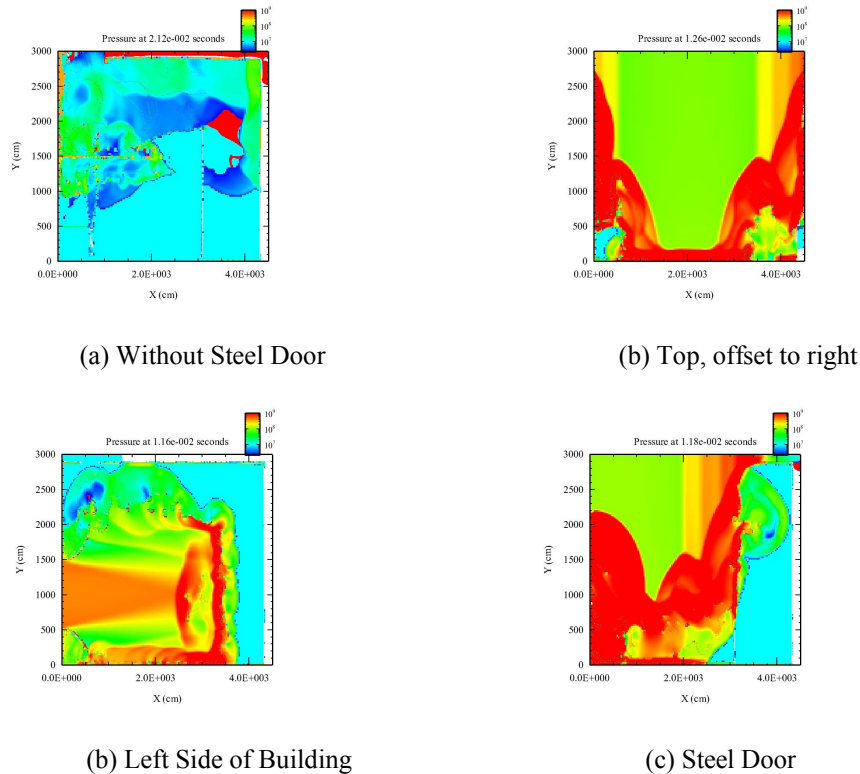


Figure 3: Pressure gradient generated from blasts

4. Recommendations and Future Studies

Structural elements that must withstand or transfer external blast pressures must be analyzed and designed accordingly. The same is true of internal elements, particularly elevated floor slabs, if windows or doors are not expected to remain intact during a blast event. Failure of these components will permit the blast pressures to propagate within the building. Although the actual blast load on an exposed element will vary over its tributary area, for design, the maximum dynamic load is typically taken as the product of this area and either the maximum pressure or a spatially average value. An organization should be pro-active in its ability to reduce the effects of terrorist activity by performing a blast vulnerability assessment plan [4]. The overall approach to conducting a vulnerability analyses is to assess the blast vulnerability due to potential terrorist acts and should entail at a minimum the following major activities:

1. Data gathering (floor plan drawings, structural information and interviews)
2. Walk downs in order to take photos of buildings or critical areas of concern
3. Confirmation of floor plans and structural information
4. Measurement of standoff distances
5. Window construction
6. Develop hydrodynamic models of buildings

Once information is gathered, the next step is to conduct a blast effect analyses (as was performed in this study) of critical buildings using a shock wave simulation code such as CTH. Finally, one should extrapolate the blast effects scenarios results to a qualitative assessment of vulnerability (preferably determine the level of protection under the UFC guidelines [5] and level of damage under DOD AMMUNITION AND EXPLOSIVES SAFETY STANDARDS guidelines [6]).

One should carefully consider the structural layout of a building and make any structural upgrades within budget to improve the hardness of a building in order to withstand the impetus of a low yield bomb. The following mitigation strategies should be considered for any installation:

1. Trim or remove vegetation within 33 feet of buildings so as to assure that a backpack size object can be easily viewed from the building and building egress areas.
2. Close off access to areas beneath buildings and/or structures near buildings and within 33 ft. of buildings.
3. Remove small trash containers near building and entrances/exits.
4. Keep access gates secured against unauthorized personnel at all times.
5. Install security fencing/gates.
6. Provide window film upgrades.
7. Provide window film and catcher system upgrades.
8. Provide blast resistant window upgrades.
9. Provide bollards and/or K-walls to restrict vehicle access.
10. Provide striping and signage to prevent or limit vehicle parking or drive-up/drop off access.
11. Provide road closure(s) and redirection of through-traffic and/or vehicle parking.
12. Provide protective upgrades to non-bearing exterior wall systems.
13. Provide structural upgrades to exterior bearing walls and/or columns.
14. Reorganize building interior areas to minimize occupant exposure to window glass and other blast debris.
15. Extend Curb lines.
16. Retrofit existing masonry buildings to resist explosions [7].

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